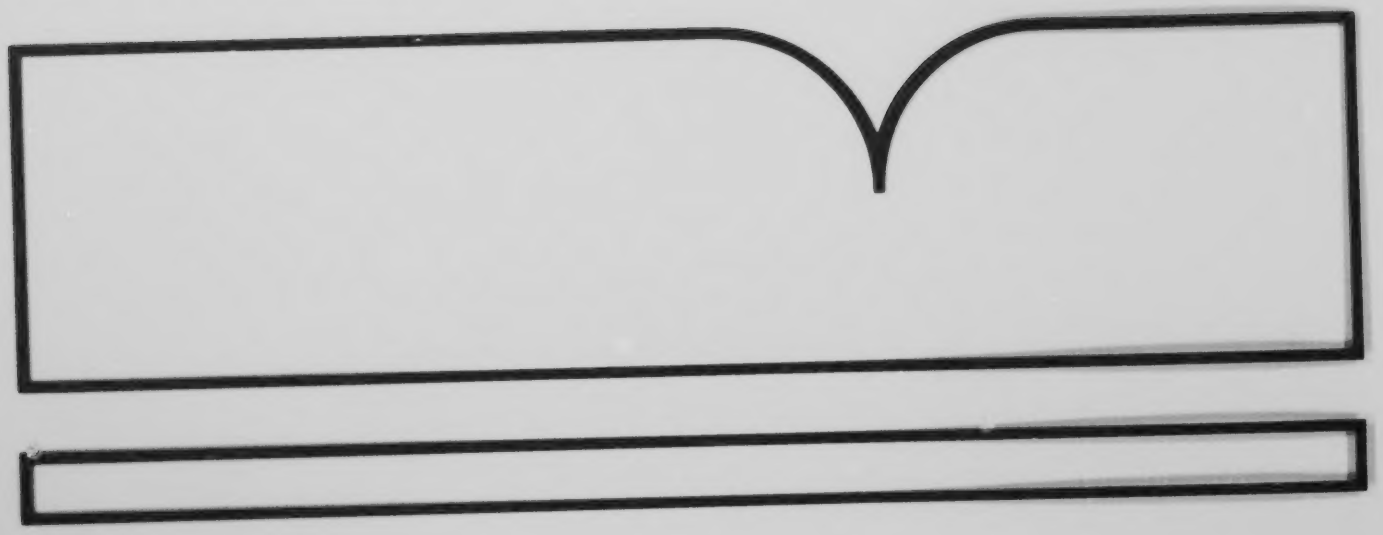
PB88-250261

Emissions of Air Pollutants from Indoor Materials: An Emerging Design Consideration

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Aug 88



U.S. Department of Commerce
National Technical Information Service
NTIS

PB88-250261

EPA/600/D-88/191
August 1988

EMISSIONS OF AIR POLLUTANTS FROM INDOOR MATERIALS: An Emerging Design Consideration

By

W. Gene Tucker
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/D-88/191	2.
3. RECIPIENT'S ACCESSION NO. PB88-250261	
4. TITLE AND SUBTITLE Emissions of Air Pollutants from Indoor Materials: An Emerging Design Consideration	5. REPORT DATE August 1988
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) W. Gene Tucker	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS See Block 12.	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. NA (Inhouse)
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development, Air and Energy Engineering Research Laboratory, Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED Published paper; 8/88
	14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES Author Tucker's mail drop is 54: his phone is 919/541-2746.

16. ABSTRACT The paper discusses the importance of indoor air quality in the acceptability of a building. The health and productivity of building occupants can be affected by the presence of certain organic chemical vapors, particles, and biological contaminants in the indoor air. Many of the materials used in buildings, either as structural materials or furnishings, or contents such as work supplies and maintenance materials, can be sources of indoor air contaminants. Concepts on material evaluation and selection are presented.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Furniture	Pollution Control	13B 15E
Buildings	Finishes	Stationary Sources	13M 11C
Emission	Maintenance Equipment	Indoor Air	14G
Design Criteria	Organic Compounds	Particulate	07C
Materials	Particles		11
Construction Materials	Biological Aerosols		13C

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 16
	20. SECURITY CLASS (This page) Unclassified	22. PRICE A03 12.95

EPA Form 2220-1 (9-73)

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

EMISSIONS OF AIR POLLUTANTS FROM INDOOR MATERIALS: AN EMERGING DESIGN CONSIDERATION

W. Gene Tucker
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, USA

ABSTRACT - Indoor air quality is an important factor in the acceptability of a building. The health and productivity of building occupants can be affected by the presence of certain organic chemical vapors, particles, and biological contaminants in the indoor air. Many of the materials used in buildings, either as structural materials or furnishings, or contents such as work supplies and maintenance materials, can be sources of indoor air contaminants. Concepts on material evaluation and selection are presented.

INTRODUCTION

Indoor air quality is an important factor in both the short- and long-term acceptability of a building. The health and productivity of building occupants can be affected by the presence of certain organic chemical vapors, particles, and biological contaminants in the indoor air. Many of the materials used in buildings, either as structural materials or furnishings, or contents such as work supplies and maintenance materials, can be sources of indoor air contaminants. The state-of-knowledge on emissions from such materials is reported in this paper. Recommendations are presented on material specification and selection during the design phase of new construction or building renovation.

Whereas indoor materials can also emit inorganic substances and particles, the major emissions in terms of quantity and chemical variety are vapor-phase organic compounds. Formaldehyde is the most widely known example, but there are typically tens to hundreds of measurable organic chemicals in indoor air. The total concentration of these substances typically ranges from tens to thousands of micrograms per cubic meter (ug/m^3). While materials are not the only sources of these compounds, they are often the most significant. Indoor materials can, therefore, be a cause of so-called "sick" building problems. One attribute of a "healthy" building is the presence of relatively low-emitting materials (1, 2).

SOURCES OF INDOOR ORGANIC COMPOUNDS

Virtually any material with a non-metallic composition has some potential for containing organic compounds that can evaporate from its surfaces and get into the air. Of the hundreds of compounds that have been measured in indoor air, 84 that can come from material sources are listed in the appendix. The "substantiated sources" are source types for which some emissions data--either quantitative or qualitative-- are available. The "potential sources" are source types that sometimes contain the compounds listed, but for which emissions data are either not available or not yet compiled. There is, of course, a tremendous range of emission rates from such materials.

The table shown below, contains typical values of emissions data derived from research studies. Note that the emission factors--the emission rate per unit of material--can vary by a factor of many thousands from one material to another. The emission rate, which depends on how much material is present, can vary over a similar range. Although emission factors and rates are very important in determining the contribution a material makes to indoor air pollution, the duration of the emissions is also important, as will be discussed later.

EMISSION TESTING PROCEDURES

The concept of testing emissions of organic compounds from indoor materials as part of indoor air quality research began in Europe about a decade ago (3). It was subsequently begun in North America (4) with most of the early emphasis on formaldehyde emissions testing (5,6).

The most common approach for such studies has been to put samples of materials into chambers through which controlled amounts of clean air are passed. Concentrations of emitted pollutants in the air exiting from the chambers are measured. In the most detailed studies, emissions are measured as a function of time (age of

Table: Typical Emission Rates for Sources in a 400 m^2 Office Area (total vapor-phase organic compounds, except as noted)

Source*	Condition	Emission factor (mg/m^2-h)**	Assumed amount (m^2)	Emission rate (mg/h)
Silicone caulk	<10 hours	13	1	13
Silicone caulk	10-100 hours	<2	1	<2
Floor adhesive	<10 hours	220	30	6600
Floor adhesive	10-100 hours	<5	30	<150
Floor wax	<10 hours	80	100	8000
Floor wax	10-100 hours	<5	100	<500
Wood stain	<10 hours	10	100	1000
Wood stain	10-100 hours	<0.1	100	<10
Polyurethane wood finish	<10 hours	9	100	900
Polyurethane wood finish	10-100 hours	<0.1	100	<10
Floor varnish or lacquer	NA	1	100	100
Particleboard	2 years old	0.2	300	60
Particleboard (HCHO)	new	2	300	600
Plywood paneling (HCHO)	new	1	1000	1000
Chipboard	NA	0.13	300	39
Gypsum board	NA	0.026	1000	26
Wallpaper	NA	0.1	1000	100
Latex-backed carpet (4-PC)	1 week old	0.15	400	60
Latex-backed carpet (4-PC)	2 weeks old	0.08	400	32
Moth cake (para)	23° C	14,000	0.1	1400
Dry-cleaned clothes (perc)	0-1 day	1	6	6
Dry-cleaned clothes (perc)	1-2 days	0.5	6	3

NOTES:
Para = paradichlorobenzene
HCHO = formaldehyde
Perc = perchloroethylene (tetrachloroethylene)
4-PC = 4-phenylcyclohexene, an odorous constituent of some latex-backed carpets
NA = not applicable

*Emissions data shown are typical only for the specific brands, models, or units that have been tested; the data do not represent all products of the source type listed. Product-to-product variability can be very high.

**Typical values selected by author based on data in "Database of Indoor Air Pollution Sources" (described in Reference 7).

material), temperature, air flow rate, area of sample per unit volume of chamber, and relative humidity.

In North America, ASTM guidelines on procedures for testing organic compound emissions from indoor sources are under development. These guidelines will recommend procedures to use in research studies conducted in small laboratory apparatus, small chambers, large chambers, and actual buildings. Procedural guidance will cover equipment specifications, experimental design, sampling and analysis, data analysis, and quality assurance (8).

More routine testing procedures, either for product certification by manufacturers or product screening by purchasers, are less developed. The current intention within the indoor air research community is first to get consensus on research procedures, and then to develop simplified versions for routine testing.

Although difficult to conduct and moderately expensive, such chamber studies are less expensive and more controllable than studies in actual buildings. If chamber data can be modeled to simulate emissions from materials under a wide range of environmental conditions, and further modeled to predict indoor concentrations and exposures, chamber studies and modeling will become valuable tools for design and selection of indoor materials.

SELECTION OF MATERIALS

Guidelines for selecting materials to ensure good indoor air quality are lacking. Aside from asbestos content (essentially zero) and formaldehyde content (at least low enough to keep indoor concentrations below about 120 ug/m^3), there are few generally accepted guidelines. Three organic compounds are currently covered by Canadian guidelines for residential indoor air quality: formaldehyde (120 ug/m^3), acrolein (50 ug/m^3), and acetaldehyde (9000 ug/m^3) (9).

One approach to selecting materials is to choose those that are likely to increase indoor concentrations of total vapor-phase organic compounds by less than 1000 ug/m^3 under normal ventilation conditions. The scientific basis for this guidance is admittedly thin at this point; it is based on very limited clinical testing (10), plus observations of indoor concentrations in new or renovated buildings that have had significant complaints of odors and irritant symptoms from occupants.

Examples of how this guideline can be used by architects, builders, or building managers are given in a following section. Note that the examples deal with total vapor-phase organic compounds. Individual pollutants for which accepted maximum indoor concentrations are established, such as formaldehyde, can be handled in a similar manner.

CONDITIONING OF MATERIALS

A material straight off the production line may have emissions that are too high for indoor use. "Conditioning" the material might make it acceptable. Generally, conditioning includes any treatment that reduces the residual content of volatile organics. This can involve airing out the material, perhaps at elevated temperature and air exchange rate, or cleaning the material some way so as to extract the volatile organic compounds. Such steps could be taken at the manufacturing site, in storage, or at the building construction site before installation. They could also be taken after installation in the building, but before occupancy. (Although coating a material to seal in volatile organics is not strictly the same, it can have the same effect on indoor air quality, and can be considered an alternative for some materials.)

To illustrate how chamber testing results can be used to evaluate the potential of conditioning, Figure 1 shows emission characteristics of a typical caulking compound. Data were obtained from the EPA material emissions testing facility (11). Cumulative emission curves are shown for the caulk tested under two different air exchange rates and at room temperature. The data show that, for an air exchange rate of 1.8 per hour, more than 90% of the emissions of organic compounds are gone after about 4 hours. At an air exchange of 0.4 per hour, it takes about 20 hours, or 5 times as long, for 90% of the volatiles to come off the caulk. If emissions from this caulk were likely to create an indoor air problem, increased ventilation before occupancy would clearly accelerate emissions and reduce the problem substantially.

Chamber data on other materials might show more or less dramatic effects of air exchange, temperature, time, and perhaps humidity on depletion of residuals. For some materials, cleaning may be more effective. Still other materials may be so resistant to conditioning or so costly to condition, that substitution of another material may be the best option.

EXAMPLES OF MATERIAL EVALUATION

To show how emission rate data can be used in evaluations for material selection and conditioning, two examples are given. One example is based on an office space that might comprise a small building or a floor of a large building. The other example deals with a more localized space, such as a work station in an office.

The first example assumes an office space of 400 m^2 and a total indoor volume of 1000 m^3. It has a ventilation system that provides 1.5 air changes per hour of outdoor air.

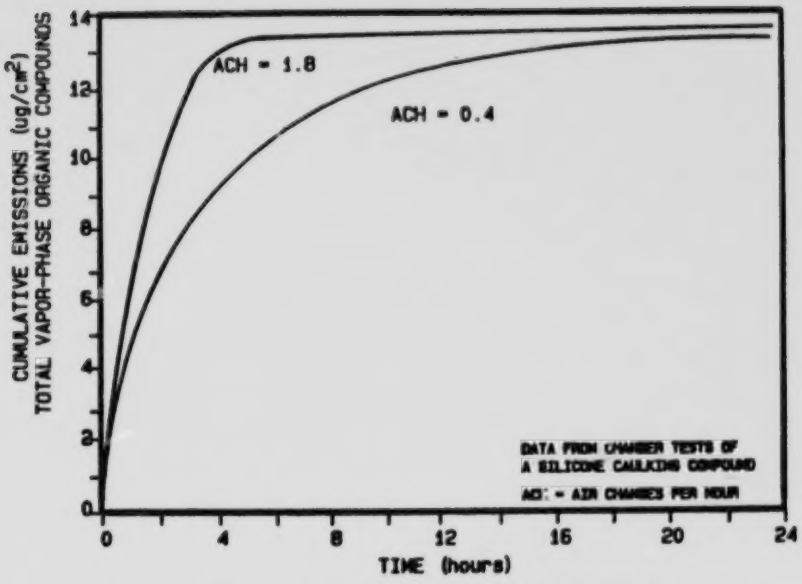


FIGURE 1. CONDITIONING BY VENTILATION. (AN EXAMPLE OF HOW INCREASED AIR EXCHANGE RATE CAN ACCELERATE EMISSIONS FROM SOME MATERIALS)

One selection criterion for materials to be used in this building is that individual materials not create an increase of greater than 1000 ug/m^3 in the office-wide average concentration of total vapor-phase organic compounds. Using a simple box model that assumes that the emissions are well mixed with outdoor ventilation air, the emission rate not to be exceeded for this situation is calculated from the equation:

[1] $ER = (C \times V \times ACH)/1000$

where ER = emission rate of total organics, mg/h

C = selected maximum contribution of the material to the indoor concentration of organics, ug/m^3

V = volume of the affected space, m^3

ACH = ventilation rate (outside air exchange rate), h^{-1}

1000 = conversion factor for mg to ug

For the situation specified above,

$ER = (1000 \times 1000 \times 1.5)/1000$
$= \underline{1500 \text{ mg/h}}$

Therefore, materials that emit more than about 1500 mg/h should be avoided to help ensure that occupants will not be irritated by organic compound emissions.

From a practical standpoint, some materials may have higher emissions in the short term. Examples would be floor waxes, such as the type listed in the table. Therefore, duration of emissions is important to consider. If the emissions are not exceedingly obnoxious, it is probably reasonable to assume that occupants will be willing to put up with the high emission rate (and therefore high indoor concentration) for a matter of hours, or a few days.

Figure 2 is a diagram that can be used to evaluate materials for this example office space. On this figure, Material A (which could be a newly waxed floor, a newly painted wall, or a new supply of graphic arts materials) is initially a high emitter, but its emission rate decays rapidly. Its emission rate falls below the line of presumed acceptability within a matter of hours or days. Conditioning of this material may not be needed (however, increased ventilation of the space--i.e., conditioning of the material in place--might be warranted).

Note also, that conditioning of rapid-decay materials such as this, when needed, is likely to be very effective at mild conditions (e.g., room temperature and low airing-out flow rates).

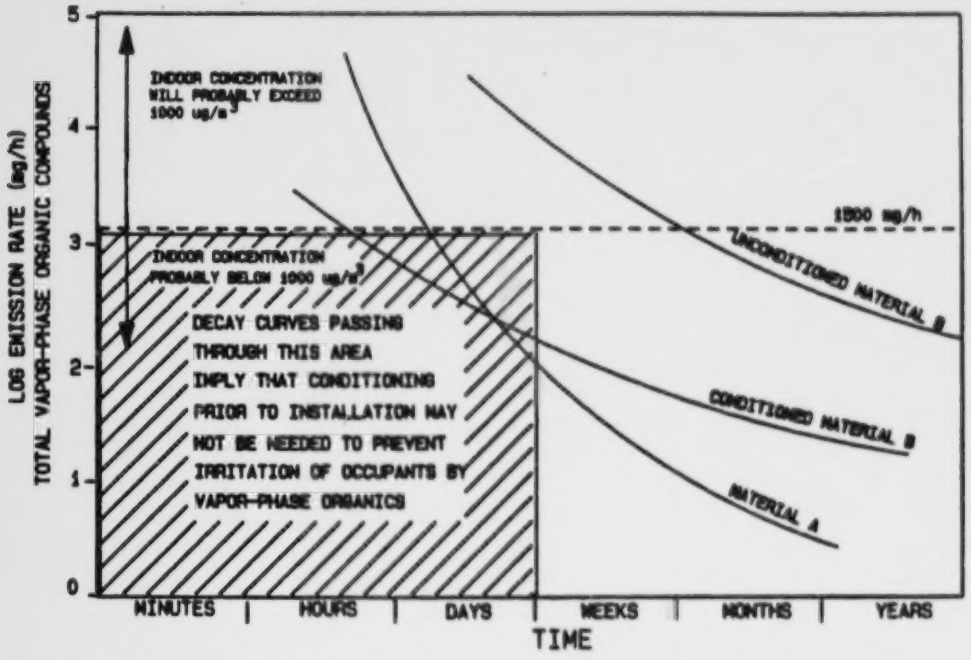


FIGURE 2. EMISSION RATE DECAY AND MATERIAL CONDITIONING: AN EXAMPLE. (EMISSIONS FROM UNCONDITIONED MATERIAL B MIGHT LEAD TO COMPLAINTS IN AN OFFICE SPACE OF 1000m^3 WITH A VENTILATION RATE OF 1.5 AIR CHANGES PER HOUR)

Material B (which could be a wall or floor covering, or new furniture) is different. It also has a high emission rate, well above the presumed acceptable level of 1500 mg/h. However, its emission rate decay is much slower; emissions remain above 1500 mg/h for a month or more. Complaints are more likely than with Material A. Use of this material would not be advisable unless it could be conditioned prior to installation. Chamber tests could be run on samples of the material to determine whether its residual content of volatiles could be reduced by airing out at elevated temperature and air exchange rate, by cleaning, or by some other process. If conditioning could change its emission characteristics to something similar to the "Conditioned Material B" curve in Figure 2, its use might be acceptable. The cost of such conditioning should of course be considered if other low-emitting materials are available.

These assumptions in the above example are worth highlighting:

- o A material emitting total vapor-phase organic compounds at a rate less than necessary to increase the indoor concentration by 1000 ug/m^3 is assumed unlikely to cause complaints of irritation by building occupants. This assumption clearly does not hold if any of the compounds emitted are especially noxious; for example, formaldehyde is odorous to many people at a concentration of about 100 ug/m^3 (12). 4-phenylcyclohexene (4-PC), a contaminant constituent in some types of carpeting, appears to be irritating to some people at concentrations of about 10 ug/m^3 (13).

- o The air in the 1000 m^3 of space is assumed to be well mixed. This is a satisfactory assumption for well-designed and -operated ventilation systems.

- o The organic vapors are also assumed to be well mixed in the space. This may not be a good assumption for materials that are only in one area of the space; concentrations in that area will tend to be higher than the example implies.

A second example can illustrate the importance of the first and third of the above assumptions. In the office space considered above, there may be several work stations. Each might occupy 10 m^2 of area (25 m^3 volume), have an outdoor air ventilation rate of 1.5 exchanges per hour, and be fully carpeted. Using equation [1]:

For total vapor-phase organic compounds (C = 1000 ug/m^3),

$$ER = (C \times V \times ACH)/1000$$

$$= (1000 \times 25 \times 1.5)/1000$$

$$= \underline{40 \text{ mg/h}} \text{ for total vapor-phase organics}$$

For 4-phenylcyclohepene (C = 10 ug/m^3),

ER = (10 x 25 x 1.5)/1000

= 0.4 mg/h

= 0.04 mg/m^2-h from the carpet

Therefore, it would be prudent to avoid using any material within the work stations that emitted more than 40 mg/h of total organics, or any carpeting that had an emission factor greater than 0.004 mg/m^2-h for 4-PC.

An alternative approach to evaluating materials is based on the use of panels of people who judge the acceptability of indoor air quality or--in a manner similar to that used by odor panels--the acceptability of emissions from sources (14). This approach has the advantage of not requiring chemical analysis of emissions and it can eliminate guesswork about acceptable concentrations. It is, however, limited to evaluation of odors and chemical irritation responses.

SUMMARY

Many materials contribute organic vapors to the air in buildings. These vapors can cause or contribute to many of the complaints that constitute the so-called sick building syndrome. Procedures for measuring emissions from indoor materials and evaluating their acceptability are now becoming available. These procedures can be used in specification or selection of materials for ensuring good indoor air quality. They can also be used in evaluating whether installing inherently low-emitting materials, or conditioning high-emitting materials prior to use, is most cost-effective. Emissions testing by material manufacturers can lead to production of low-emitting materials, and conditioning guidelines for builders and building managers.

REFERENCES

1 Tucker, W.G. Air pollutants from surface materials: factors influencing emissions, and predictive models. Presented at Healthy Buildings '88, Stockholm, 1988.

2 Fanger, P.O., Lauridsen, J., Bluyssen, P., and Clausen, G. Air pollution sources in offices and assembly halls, quantified by the olf unit. Energy and Buildings, 1988, vol. 12, pp. 7-19.

3 Mølhave, L. Indoor air pollution due to organic gases and vapors of solvents in building materials. Environment International, 1982, vol. 8, pp. 117-127.

4 Hodgson, A.T., Girman, J.R., Newton, A.S., and Winkes, A. Emissions of volatile organic compounds from architectural materials with indoor applications. Lawrence Berkeley Laboratory Report LBL-17130, 1983.

5 Matthews, T.G., Reed, T.J., Tromberg, B.J., Daffren, C.R., and Hawthorne, A.R. Formaldehyde emissions from consumer and construction products: potential impact an indoor formaldehyde concentrations. In B. Berglund et al. (Eds.), Indoor Air: Proceedings of the 3rd International Conference on Indoor Air Quality and Climate. Stockholm: Swedish Council for Building Research, 1984, vol. 3, pp. 115-120.

6 Pickrell, J.W., Mokler, F.V., Griffin, L.C., and Hobbs, C.H. Formaldehyde release coefficients from selected consumer products. Env. Sci. & Tech., vol. 17, 1983, pp. 753-757.

7 White, J.B., Reaves, J.C., Reist, P.C., and Mann, L.S. A database on the sources of indoor air pollution emissions. Presented at ASHRAE Conference IAQ '88, Atlanta, 1988.

8 Personal communication, 1988. Levin, H. ASTM Subcommittee D22.05.

9 Exposure guidelines for residential indoor air quality. A report of the Federal-Provincial Advisory Committee on Environmental and Occupational Health. Department of National Health and Welfare. Ottawa, 1987.

10 Mølhave, L., Bach, B., and Pedersen, O.F. Human reactions to low concentrations of volatile organic compounds. Environment International, vol. 12, 1986, pp. 167-175.

11 Tichenor, B.A., Jackson, M.D., and Merrill, R.G. Measurement of organic emissions from indoor materials - small chamber studies. Proceedings of the 1986 EPA/APCA Symposium on Measurement of Toxic Air Pollutants. Report EPA-600/9-86-013 (NTIS PB87-182713), 1986, pp. 86-94.

12 Berglund, B., Berglund, U., Högman, L., Johansson, I., and Lindvall, T. Measurement of formaldehyde odor indoors. In P.O. Fanger (Ed.), Proceedings of the CLIMA 2000 World Congress on Heating, Ventilating, and Air Conditioning. Copenhagen: VVS Kongres - VVS Messe, 1985, vol. 4, pp. 251-256.

13 Van Ert, M.D., Clayton, J.W., Crabb, C.L., and Walsh, D.W. Identification and characterization of 4-phenylcyclohexene - an emission product from new carpeting. University of Arizona, College of Pharmacy, Tucson, AZ, 1987.

14 Fanger, P. Introduction of the olf and decipol units to quantify air pollution perceived by humans indoors and outdoors. Energy and Buildings, 1988, vol. 12, pp. 1-6.

15 Samfield, M. Personal communication, 1988.

APPENDIX
SOURCES OF INDOOR ORGANIC COMPOUNDS
(from Reference 15; see explanatory notes at end of this table)

COMPOUND[a]	FORMULA	SUBSTANTIATED SOURCES[b]	POTENTIAL SOURCES[c]
FORMALDEHYDE	CH_2O	unvented radiant gas space heaters, upholstery fabric, latex-backed fabric, plywood, particleboard, carpets, paneling, new clothing, fiberglass, paper plates & cups, ceiling panels, airducts, unvented range-top burner, unvented gas oven, urea foam insulation, floor covering, wallpaper, caulking compounds, jointing compound, floor varnish, adhesive, fiberboard, chipboard, linoleum, floor lacquer, calcium silicate sheet, gypsum board, tobacco smoke	
METHYLENE CHLORIDE	CH_2Cl_2	paint removers, aerosol finishers	
CARBON TETRACHLORIDE	CCl_4	grease cleaners	
CHLOROFORM	$CHCl_3$	water, clothes washer	
BROMOFORM	$CHBr_3$		medicinals
TRICHLOROFLUOROMETHANE (F-11)	CCl_3F	refrigerant	
TETRACHLOROETHYLENE	C_2Cl_4	dry cleaning	
1,1,1-TRICHLOROETHANE	$C_2H_3Cl_3$	dry cleaning, cleaning fluid	
TRICHLOROETHYLENE	C_2HCl_3		solvent for paints and varnishes, degreasing in dry cleaning
ACETIC ACID	$C_2H_4O_2$	tobacco smoke	food preservative, cooking, solvent for gums, resins, volatile oils
ACETALDEHYDE	C_2H_4O		perfumes, flavors, dyes, tobacco smoke
ETHANOL	C_2H_6O	fiberboard	solvent, antifreeze, tobacco smoke

(continued)

ISOPROPANOL	C_3H_8O	particleboard	antifreeze, solvent for gums, shellac, essential oils, cosmetics
ACETONE (PROPANONE)	C_3H_6O	lacquer solvent	tobacco smoke
PYRUVIC ACID	$C_3H_4O_3$		medicinal ointments
ETHYLACETATE	$C_4H_8O_2$	linoleum floor covering	artificial fruit essences, solvent for varnishes & lacquers; used in manuf. perfumes & artificial leather
DIETHYLAMINE	$C_4H_{11}N$		used in resins, dyes, pharmaceuticals; used in manuf. rubber
DIMETHYLACETAMIDE	$C_4H_{10}ON$		solvent for many organic reactions
n-BUTYLACETATE	$C_4H_{10}O_2$	floor lacquer	
i-BUTYLACETATE	$C_4H_{10}O_2$	floor lacquer	
1,4-DIOXANE	$C_4H_8O_2$		solvent for many oils, waxes, dyes, cellulose acetate
n-BUTANOL	$C_4H_{10}O$	edge sealing moulding tape, jointing cmpd., cement flagstone, linoleum floor covering, floor lacquer	flavors, perfumes, industrial cleaners, paint removers
i-BUTANOL	$C_4H_{10}O$	ditto	tobacco smoke
2-BUTANONE (MEK)	C_4H_8O	floor/wall covering, calcium silicate sheet, fiberboard, caulking cmpds., particleboard, tobacco smoke	synthetic resins, tobacco smoke
2-ETHOXY-ETHANOL (Cellosolve)	$C_4H_{10}O_2$	epoxy paint	
PENTANE	C_5H_{12}	tobacco smoke	
1-AMYL ALCOHOL	$C_5H_{12}O$		solvent in organic syntheses
PROPYL ACETATE	$C_5H_{10}O_2$		flavors, perfumes, plastics

(continued)

n-HEXANE	C_6H_{14}	chipboard, gypsum board, insulation foam, floor covering, wall paper, tobacco smoke	
CYCLOHEXANE	C_6H_{12}	tobacco smoke	solvent for lacquers and resins, paint & varnish remover
CYCLOHEXANONE	$C_6H_{10}O$		solvent for many resins and for DDT, also for fats & waxes
HEXANAL	$C_6H_{12}O$	polyurethane wood finish	
4-METHYL-2-PENTANONE	$C_6H_{12}O$	floor/wall covering, tobacco smoke	
METHYLCYCLOPENTANE	C_6H_{12}	tobacco smoke	
2-METHYLPENTANE (Isohexane)	C_6H_{14}	chipboard, gypsum board, insulation foam, floor covering, wall paper, tobacco smoke	
3-METHYLPENTANE	C_6H_{14}	tobacco smoke	
BENZENE	C_6H_6	smoking, adhesives, spot cleaners, paint remover, particleboard, tobacco smoke	
CHLOROBENZENE	C_6H_5C		solvent for paint: used in manuf. DDT & phenol
o-DICHLOROBENZENE	$C_6H_4C_2$	deodorizers, moth crystals	
m-DICHLOROBENZENE	$C_6H_4C_2$	deodorizers, moth crystals	
p-DICHLOROBENZENE	$C_6H_4C_2$	deodorizers, moth crystals	
HEXACHLOROBENZENE	C_6C_6	fungicide	
TETRACHLOROPHENOL	$C_6H_2C_4O$	wood preservative	
2-ETHOXYETHYLACETATE	$C_6H_{12}O_3$	floor lacquer, epoxy paints	
PENTACHLOROPHENOL	C_6HC_5O	wood preservative	
ISO-BUTYLACETATE	$C_6H_{12}O_2$		flavorings, solvent
BUTYLACETATE	$C_6H_{12}O_2$	floor lacquer	

(continued)

TOLUENE	C_7H_8	solvent-based adhesive, water-based adhesive, edge-sealing moulding tape, wallpaper, jointing cmpd., calcium silicate sheet, floor covering, vinyl coated wallpaper, caulking cmpds., paint, chipboard, linoleum floor covering, kerosene heaters, tobacco smoke	
BUTYL ACRYLATE	$C_7H_{11}O_2$		used as monomer in manuf. of polymers & resins for textile & leather finishes
HEPTANE	C_7H_{16}	floor covering, floor varnish, kerosene heaters	
BENZALDEHYDE	C_7H_6O	fiberboard, particleboard	
ETHYLBENZENE	C_8H_{10}	floor/wall covering, insulation foam chipboard, caulking cmpds., jointing cmpd., fiberboard, calcium silicate sheet, adhesives, floor lacquer, grease cleaners	
STYRENE	C_8H_8	insulation foam, jointing cmpd., fiberboard, tobacco smoke	
XYLENES	C_8H_{10}	adhesives, jointing cmpd., wall-paper, caulking cmpds., floor covering, floor lacquer, grease cleaners, shoe dye, tobacco smoke, kerosene heaters varnish, kerosene heaters	
NONANE	C_9H_{20}	wallpaper, caulking cmpds., floor covering, chipboard, adhesives, cement flagstone, jointing cmpd., floor varnish, kerosene heaters, floor wax	
ETHYL TOLUENE	C_9H_{12}	floor wax	
o-ETHYLTOLUENE	C_9H_{12}	floor wax	
m,p-ETHYLTOLUENE	C_9H_{12}	floor wax	
m-ETHYLTOLUENE	C_9H_{12}	floor wax	

(continued)

QUINOLINE	C_9H_7N		used in manuf. of dyes; solvent for resins
ISOQUINOLINE	C_9H_7N		used in synthesis of dyes and insecticides, rubber accelerator
INDANE (Hydrindene)	C_9H_{10}		constituent of coal tar
1,2,3 TRIMETHYLBENZENE	C_9H_{12}	floor/wall covering, floor wax	
1,2,4 TRIMETHYLBENZENE	C_9H_{12}	floor/wall covering, linoleum floor covering, caulking cmpds., vinyl coated wallpaper, jointing cmpd., cement flagstone, floor varnish, chipboard, floor wax	
1,3,5 TRIMETHYLBENZENE	C_9H_{12}	caulking compounds, floor/wall covering, floor wax	
n-PROPYLBENZENE	C_9H_{12}	adhesives, floor/wall covering, chipboard, paint, caulking cmpds., insulation foam, kerosene heaters	
ISOPROPYLBENZENE	C_9H_{12}	floor/wall covering, paint, insulation foam, jointing cmpd.	
DECANE	$C_{10}H_{22}$	jointing cmpd., chipboard, floor varnish, wall paper, fiberboard, cement flagstone, floor/wall covering, adhesives, caulking cmpds., kerosene heaters	
n-BUTYLBENZENE	$C_{10}H_{14}$		solvent
LIMONENE	$C_{10}H_{16}$	paint, adhesives, chipboard, detergents	
PINENE	$C_{10}H_{16}$		used in manuf. of camphor, insecticides, solvents, plasticizers, & perfumes
a-PINENE	$C_{10}H_{16}$	cement flagstone, fiberboard, gypsumboard, adhesive, insulation sheets, chipboard, calcium silicate sheet	

(continued)

a-TERPINENE	$C_{10}H_{16}$		oil of lemon
CAMPHENE	$C_{10}H_{16}$		occurs in many essential oils
CAMPHOR	$C_{10}H_{16}O$	moth crystals	
NAPHTHALENE (Tetralin)	$C_{10}H_{12}$	moth crystals	
UNDECANE	$C_{11}H_{24}$	wallpaper, gypsum board, floor/wall covering, jointing cmpd., chipboard, floor varnish, paints, paint removers	
DODECANE	$C_{12}H_{26}$	floor varnish, floor/wall covering, kerosene heaters	
4-PHENYLCYCLOHEXENE	$C_{12}H_{14}$	latex-backed carpet	
NONYLPHENOL ISOMERS	$C_{15}H_{24}O$		used in manuf. of lubricating oil additives, resins, plasticizers, & surface active agents
DIBUTYLPHTHALATE	$C_{16}H_{22}O_4$	plastics	

NOTES:

[a]Selected compounds that have been measured in indoor air and that may have come from material sources.

[b]Source types for which quantitative data on emissions have been obtained by chamber tests, or for which qualitative data are available (e.g., from headspace testing).

[c]Source types known to contain the compound. Not all products of the source type will necessarily have the compound, however.